

Water on the land



In this unit students gain an understanding of rivers and their landforms, flooding, and how rivers are managed. There are seven key ideas in this unit:

- 1. The shape of river valleys changes as rivers flow downstream due to the dominance of different processes.**
- 2. Distinctive landforms result from different processes as rivers flow downstream**
- 3. The amount of water in a river fluctuates due to a number of reasons**
- 4. Rivers flood due to a number of physical and human causes. Flooding appears to be an increasingly frequent event**
- 5. The effects and responses to floods vary between areas of contrasting levels of wealth.**
- 6. There is discussion about the costs and benefits of hard and soft engineering and debate about which is the better option.**
- 7. Rivers are managed to provide a water supply. There are a variety of issues resulting from this.**

1. The shape of river valleys changes as rivers flow downstream due to the dominance of different processes

Erosion

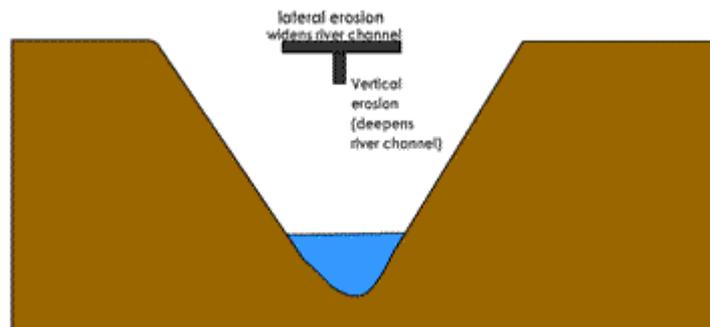
There are four types of erosional processes in a river:

Abrasion: The erosion of the river bottom and the riverbank by material being carried by the river itself.

Attrition: The rocks and pebbles being carried by the river crash against each other, wearing them down to become smaller, rounded pebbles.

Solution: The chemical erosion of the rocks of the riverbank by the slightly acidic water. This occurs in streams running through rocks such as chalk and limestone.

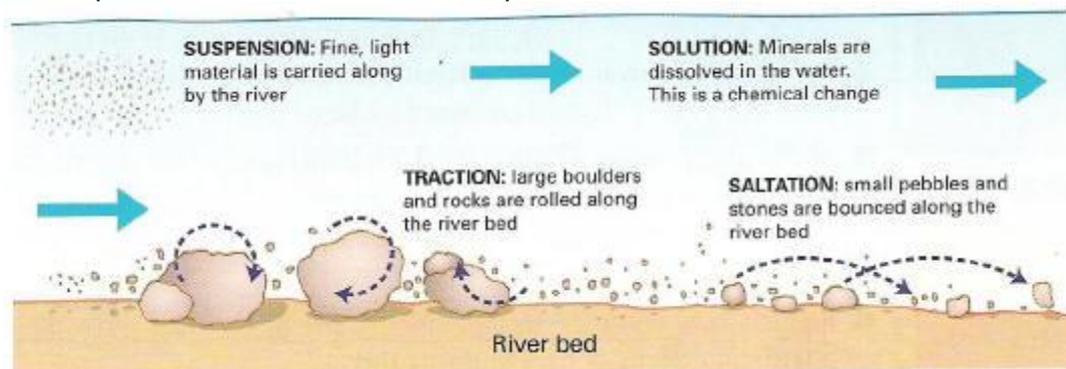
Hydraulic Action: The water forces air to be trapped and pressured into cracks in the rocks on the bank of the river. This constant pressure eventually causes the rocks to crack and break apart.



Erosional processes [animation](#)

Transportation

Rivers transport material in four different ways.



The amount of load being carried depends on:

- the volume of water - the greater the volume, the more load it can carry
- the velocity - a fast-flowing river has more energy to transport and can move larger particles
- the local rock types - some rocks (e.g. shales) are more easily eroded than others (e.g. granite)

As a river flows downstream the amount of load tends to increase and the size of sediments decrease.

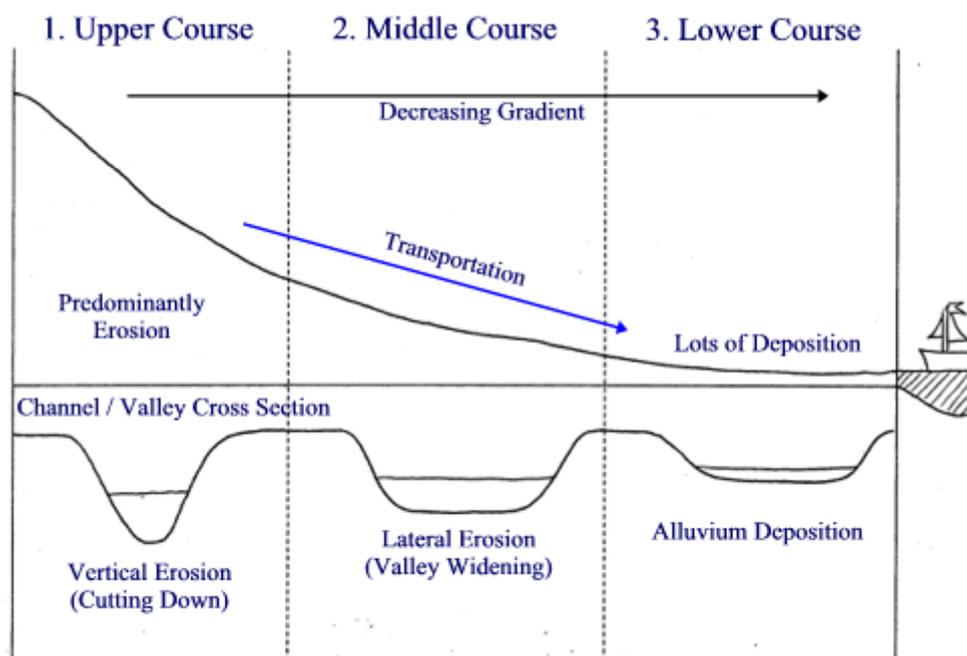
Deposition

Deposition is when the river 'drops' the sediment which it is carrying. This happens when a river lacks sufficient energy to transport the load it is carrying. Deposition is encouraged by several factors:

- a river carrying a large load, providing more material to deposit
- a reduction in velocity e.g. inside of a meander, on entering lake/sea
- a fall in the volume of water e.g. at times of low flow during a period of drought

Long Profile

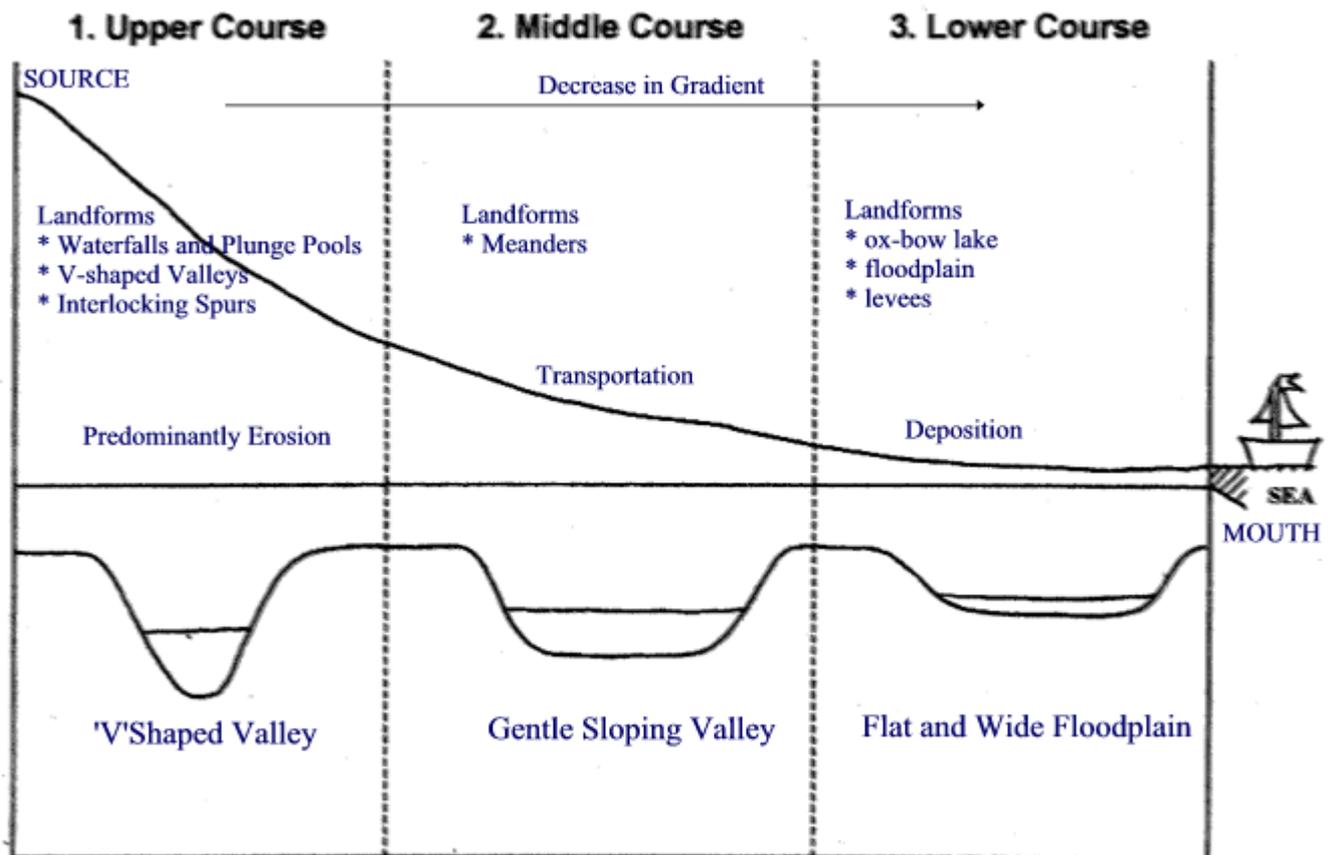
Processes vary along the course of the river and as a result the shape of the channel changes downstream.



2. Distinctive landforms result from different processes as rivers flow downstream.

Rivers have an upper, middle and lower course. Each of these sections have different dominant processes resulting in different features.

[BBC Bitesize overview video](#)



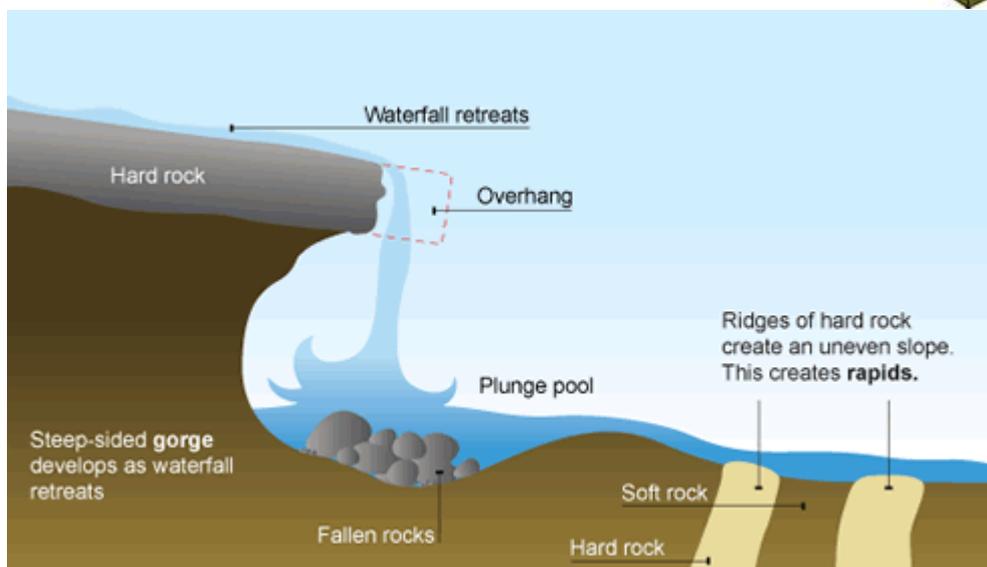
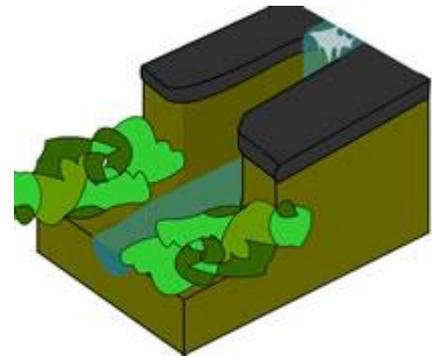
Landforms resulting from erosion

In the upper course erosion is the dominant process creating **V-shaped valleys**, **interlocking spurs** and **waterfalls**.

In the upper course of the river, the river cuts rapidly downwards, as the main direction of erosion is vertical. This causes the most distinctive river feature, the **V-shaped valley**. Freeze-thaw weathering and other processes create loose material on the valley sides which are then washed into the river from the steep valley sides during times of heavy rainfall, adding to the material being carried by the river. This means that abrasion can continue to steepen the valley and the river cuts further downwards. **Interlocking spurs** are created when the river has to flow around an obstruction for example, hard rock.



When a river flows over alternating layers of hard/soft rocks **waterfalls** can be formed. As the river flows over the hard rock onto soft rock, the soft rock will be more easily eroded. A plunge pool is created and processes such as abrasion and hydraulic action cause further erosion of the soft, less resistant, rock. Over time this creates an overhang which eventually, due to gravity, collapses under its own weight. This process happens repeatedly which means that the waterfall gradually retreats upstream creating a **gorge**.



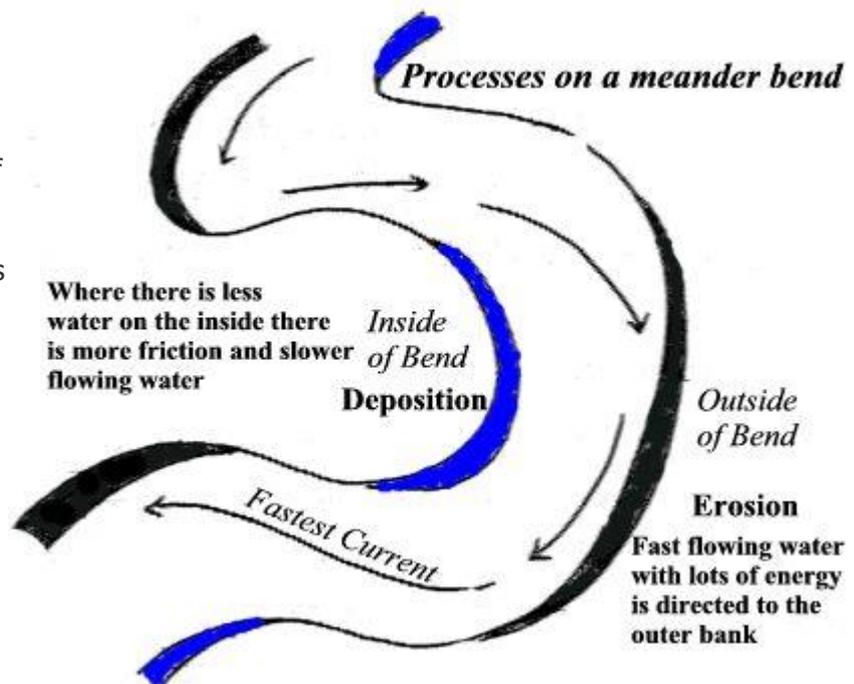
Gorge

BBC Bitesize - upper course features

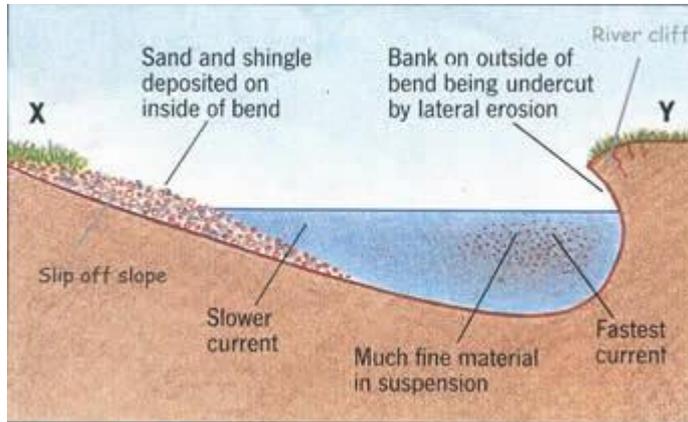
Landforms resulting from erosion and deposition

In the middle section the river has more energy and a high volume of water. Erosion is now mainly lateral and it has widened the river.

Meanders are bends in the river. They are formed by a combination of erosion and deposition. The faster water travels around the outside of the bend, eroding the banks through abrasion and hydraulic action. This creates a steep river cliff. On the inside of the bend the velocity is much slower and consequently, deposition



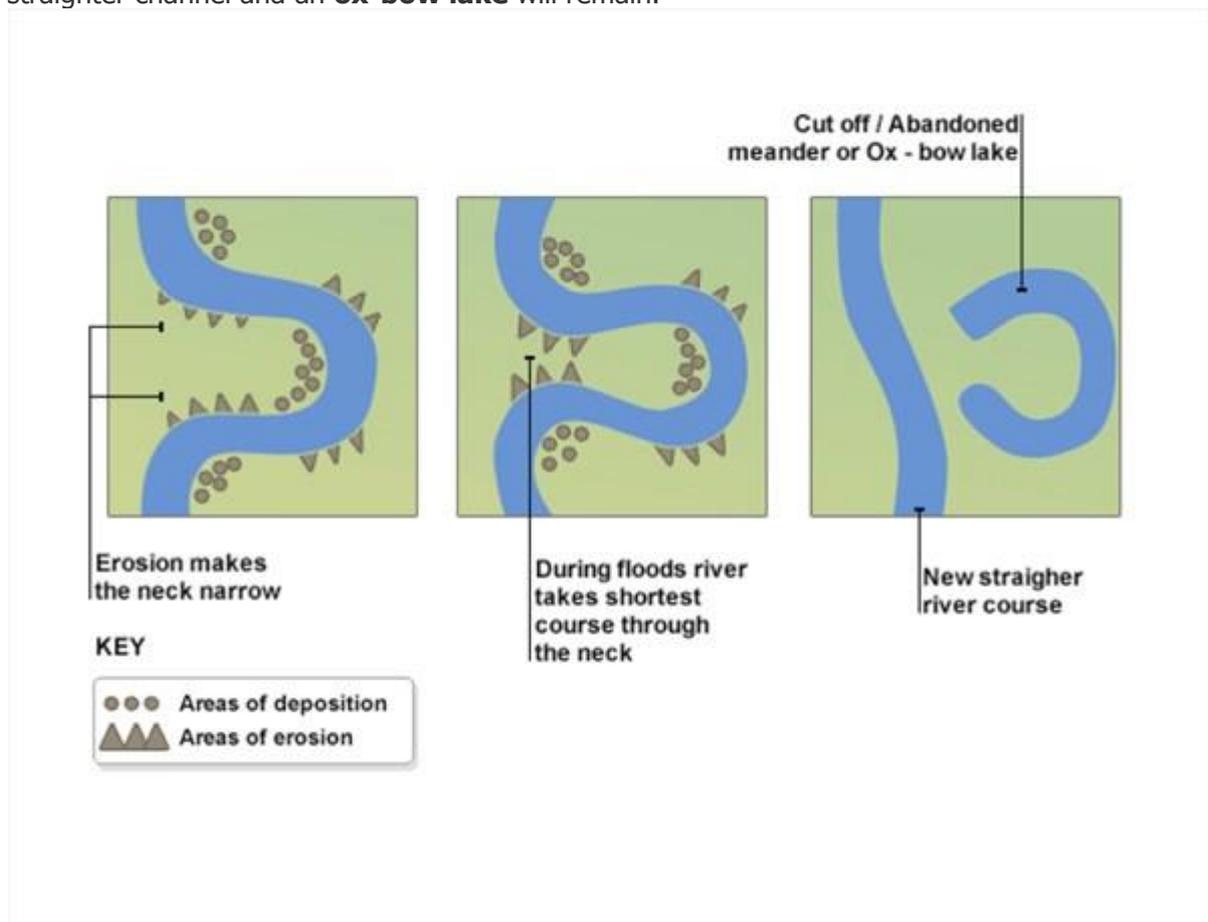
occurs creating a slip-off slope.



[Video on formation of meanders and ox-bow lakes](#)

[BBC Bitesize - middle course features](#)

Over time the meander becomes more pronounced and the 'neck' of the meander becomes smaller. Eventually the river will break through the neck of the meander to create a new, straighter channel and an **ox-bow lake** will remain.

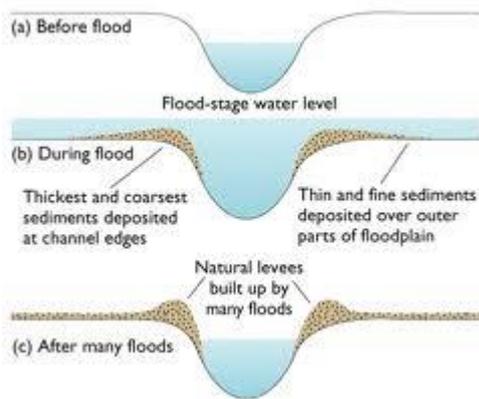
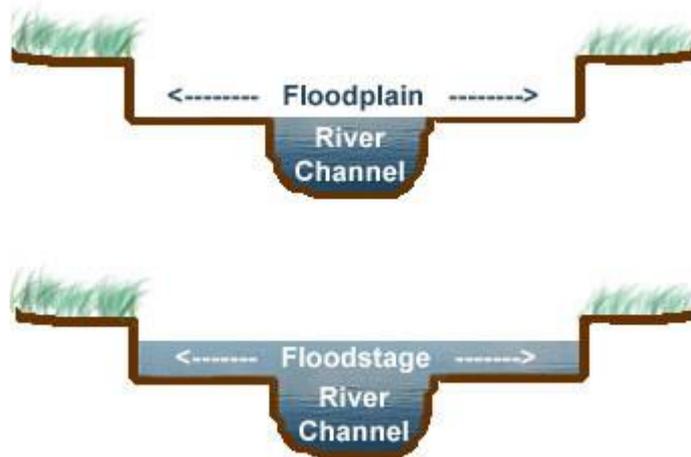


Landforms resulting from deposition

In the lower course the river has a high volume. The river channel is now deep and wide and the surrounding landscape is flat. However, as the river reaches the end of its course, energy is low and deposition occurs.

The **floodplain** is a wide, flat area of land either side of the river in its lower course. It is covered with water during times of flood. Lateral erosion and the formation/migration of meanders have caused the floodplain to get wider, interlocking spurs have been eroded away.

When a river floods onto the floodplain the water becomes shallow and the river's velocity decreases leading to deposition.



Natural **levees** form beside a river's banks. They are formed when the river deposits material as it floods. During a flood the river will deposit its heaviest material first (i.e. closest to the banks). Over the years this material builds up to create a levee. The floodplain also gets built up with the fine sediment to create alluvium which makes the floodplain very fertile.

Deltas are found at the mouth of large rivers. They are formed when the river deposits its material faster than the sea can remove it.

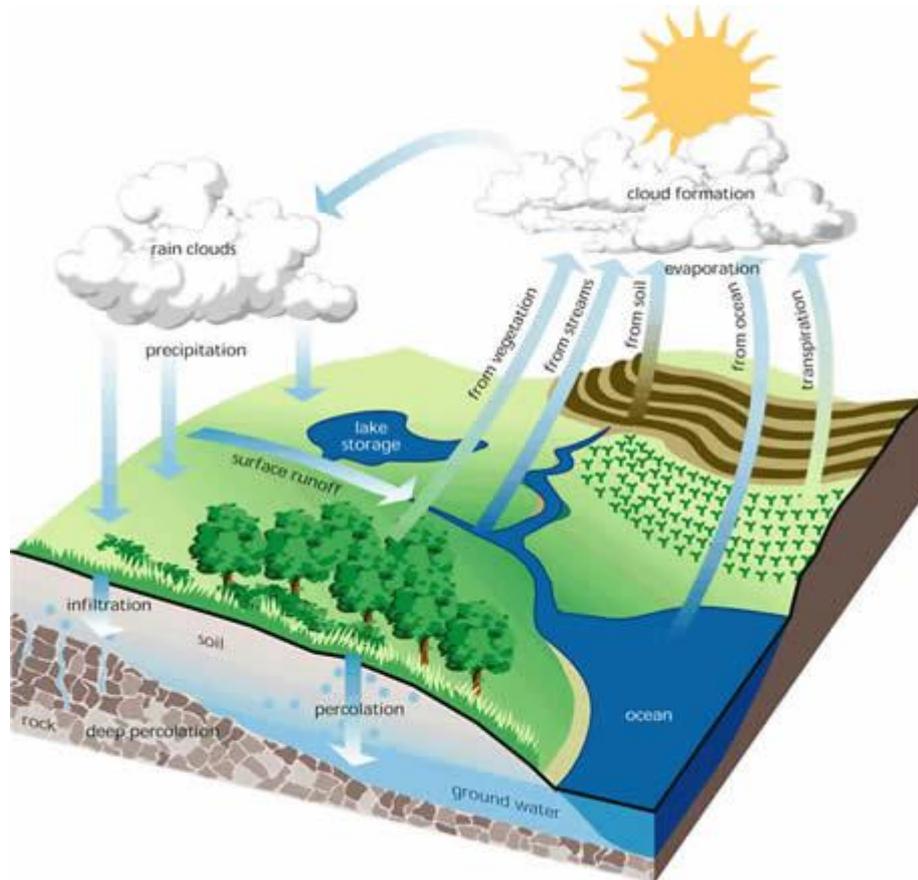
River landforms case study

You need to be able to give examples of river landforms. We are using the River Tees in the northeast of England as our main example.

Upper	Middle	Lower
V-shaped valley and interlocking spurs - The Pennines section of the R. Tees	Meanders - R. Tees between Darlington and Yarm	Floodplain - R. Tees at Barnard Castle
Waterfall - High Force, R. Tees	Ox-bow lake - downstream of Darlington on R. Tees	Levees - downstream of Darlington on R. Tees
		Delta - Mississippi River, USA

3. The amount of water in a river fluctuates due to a number of reasons

Hydrological cycle



Precipitation: any source of moisture reaching the ground (e.g. rain, snow, hail)

Interception: water being prevented from reaching the surface by trees or grass

Surface storage: water held on the ground surface (e.g. puddles)

Infiltration: water sinking into soil/rock from the ground surface

Soil storage/soil moisture: water held in the soil layer

Percolation: water seeping deeper into rock

Groundwater: water stored in rock

Transpiration: water lost through pores in vegetation

Evaporation: water lost from ground

Surface run-off: water flowing on top of the ground

Throughflow: water flowing through the soil layer

Groundwater flow: water flowing through the rock layer

Water table: current upper level of saturated rock/soil where no more water can be absorbed

Drainage basin

Source - The beginning of the River

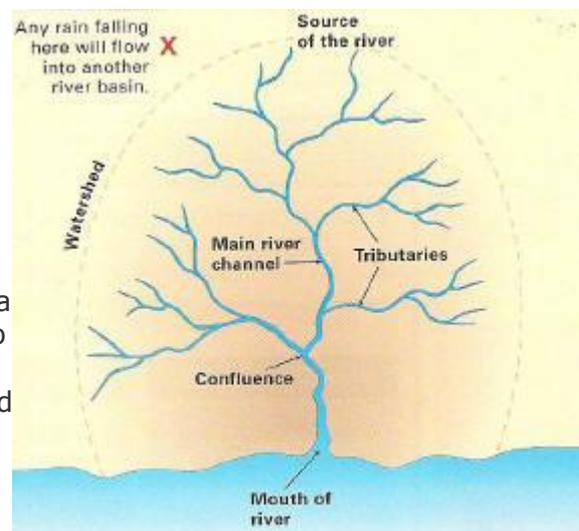
Confluence - Where two rivers meet

Watershed - An area of high land between two drainage basins

Mouth - Where a river flows into a lake or the sea

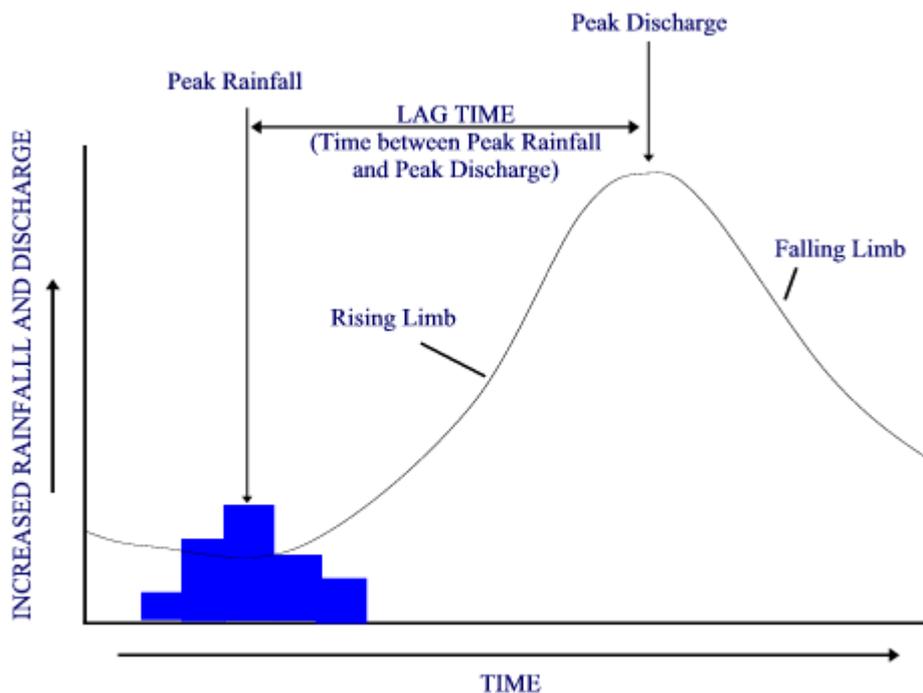
Tributary - A small river or stream that flows into a larger river

Drainage Basin - The area drained by a river and its tributaries



Storm Hydrographs

A storm hydrograph is used to show how a river responds to a period of rainfall. The shape of the graph helps to you decide whether that basin is likely to flood or not. A graph with a short lag time and a high peak discharge is more likely to flood than one with a longer lag time and lower peak discharge.



Discharge - this is the amount of water in a river at any given point and time. Discharge is measured in cumecs (cubic metres per second)

Velocity - speed of a river (measured in metres per second)

Hydrograph - a graph showing changes in river discharge over time in response to a rainfall event.

Lag time - the

time taken between peak rainfall and peak discharge

Rising Limb - shows the increase in discharge on a hydrograph

Falling Limb - shows the return of discharge to normal / base flow on a hydrograph

Peak Rainfall - maximum rainfall (mm)

Peak Discharge - maximum discharge (cumecs)

Guide to interpreting hydrographs

Factors affecting the shape of hydrographs:

- **Impermeable rocks** (e.g. granite) and soil (e.g. clay) will not allow water to pass through, resulting in large amounts of surface runoff and a greater flood risk as rivers respond quickly, this results in a short lag time. **Permeable rocks** and soil have a high infiltration capacity and will absorb water quickly, reducing surface runoff, this results in a longer lag time. **Porous rock** allow water to be stored in them or pass through them and **pervious rock** allows water to flow along faults and bedding planes.
- A drainage basin with a **steep gradient** will result in faster surface runoff and a **shorter lag time** than where the gradient is less steep allowing more time for infiltration to occur.

- **Heavy rain** results in rapid saturation of the upper soil layers and the excess water therefore reaches streams quickly as surface runoff (**short lag time**). **Slow light rain** can be absorbed by infiltration and the river takes longer to respond to rainfall as water takes longer to pass through the drainage basin via throughflow and groundwater flow (**longer lag time**).
- **Previous weather conditions: prolonged rainfall** may mean the soil has already been saturated by heavy rain. Its infiltration capacity will be reduced and more rain will flow as surface runoff. If the soil is **dry** it will be able to absorb more water during infiltration and therefore the lag time will be longer. If the ground surface is **frozen** lag time is short as water cannot infiltrate and passes quickly to the river as runoff
- **Impermeable man made surfaces** such as concrete and tarmac are impermeable therefore rivers in urban drainage basins tend to have **short lag times** due to higher amounts of surface runoff and drainage systems taking water to rivers quickly.
- **Vegetated areas** help to reduce flood risk by increasing the time it takes for water to reach a river (**longer lag time**) by encouraging infiltration (roots opening up the soil), intercepting water by their leaves and taking up water in their roots. Areas cleared by **deforestation** will respond quickly to rainfall due to the reduced interception
- **Large drainage basin** - water will take longer to reach the river (long lag time). **Small drainage basin** - water will enter the river quicker (short lag time)
- The **presence of a dam** will allow flow to be controlled, reducing flood risk and allowing rivers to gradually respond to heavy rainfall in a controlled way;

4. Rivers flood due to a number of physical and human causes. Flooding seems to be an increasingly frequent event.

A flood occurs when a river bursts its banks and water spills onto the floodplain.

Heavy rain tends to cause flooding. The faster the water reaches the river channel, the more likely it is to flood. The fastest way in which water can reach the river is via surface runoff.



The nature of the landscape will alter the speed at which the water will reach the river. The landscape can be affected by physical and human factors.

Physical Factors

Prolonged rainfall: ground will become saturated and impermeable so there will be higher amounts of surface runoff.

Intense rainfall: ground will be unable to infiltrate the high amount of water so there will be higher rates of surface runoff.

Steep-sided channel: faster surface run-off will mean the water reaches the river quickly causing it to overflow.

Lack of vegetation: trees and plants intercept precipitation. If there is little interception then there will be higher surface runoff.

Impermeable rock: water will not be intercepted or percolated so there will be more surface runoff.

Colder temperatures: if the ground is frozen it will become impermeable so there will be higher amounts of surface runoff.

Hard baked ground: ground cannot infiltrate all the rainfall so there will be higher rates of surface runoff.

Snow melt: melting snow can lead to saturated ground and higher rates of surface runoff.

Human Factors

Urbanisation: water will not be intercepted so there will be more surface runoff and it will be faster.

Deforestation: less interception so more surface runoff.

5. The effects of and responses to floods vary between areas of contrasting levels of wealth.

For this section of the unit you need two case studies, one from a richer area of the world - Boscastle, UK and one from a poorer part of the world - Dhaka, Bangladesh. You need to be able to compare and explain the different effects of and responses to flooding.

		Boscastle, UK	Dhaka, Bangladesh
		16th August 2004 Village built at the confluence of the River Jordan and the River Valency Video	Severe floods in 1998 and 2004 Confluence of three rivers: Meghna, Ganges, Brahmaputra Video
Causes	Natural	Torrential rain: over 500mm rain fell in 4 hours, remnants of Hurricane Alex. Weather system remained stationary over area due to converging winds. Small catchment area (about 23km ²) Impermeable upland area (Bodmin Moor) Steep-sided valleys Extremely wet summer, by August ground was saturated.	Confluence of three large rivers Snow melt from Himalayas 70% land area <1m above sea level Cyclones create storm surges Increased surface runoff and more soil erosion means silt blocks river channels reducing carrying capacity of river 80% floodplain and delta makes Bangladesh very susceptible to flooding Monsoon rainfall
	Human	Building along river Construction of small bridges across river (trapped material behind them creating small dams) River narrowed through Boscastle reducing capacity Deforestation in valleys	Deforestation in Himalayas Ganges diverted for irrigation increasing silt deposition Rapid unplanned urbanisation in Dhaka
Effects	Social	Destroyed homes Stress and anxiety for local people Cars belonging to more than 1,000 people washed away	Hundreds killed Millions made homeless Contaminated water led to disease
	Economic	25 business properties destroyed Bridges and roads damaged 4 footbridges washed away Visitor centre destroyed Area relies on tourism for 90% income, most of which earned in summer	Over 900 bridges destroyed 15,000km road damaged Crops lost leading to food shortages Financial losses for businesses and shops Communications damaged making co-

	<p>months. Floods dramatically affected earnings.</p> <p>Insurance companies paid out an estimated £20 million to repair damaged property</p>	<p>ordinating rescue efforts difficult</p>
Environmental	<p>Gardens and pavements destroyed by weight of floodwater</p>	<p>Agricultural land flooded and contaminated by polluted water</p>
Responses Short-term	<p>Major incident declared at 5pm. RAF search and rescue were alerted to rescue trapped people. No-one died mainly due to the rapid response of the emergency services.</p>	<p>Farmers provided with free seeds</p> <p>Foreign aid (including £21million from UK)</p> <p>Water purification tablets</p> <p>Food aid</p>
Long-term	<p>To reduce the risk of future floods, a £4.6 million flood defence scheme was completed in 2008.</p> <p>Low bridges removed</p> <p>River widened through Boscastle</p> <p>New flood defence wall built in village centre</p> <p>River bed lowered by an average of 0.75m</p> <p>Trees near to river removed</p> <p>Landowners encouraged to maintain vegetation cover on valley sides</p>	<p>Dhaka Integrated Flood Protection Project</p> <p>Cluster villages (raised by 2m) and raised homesteads (individual homes raised by 2m on earth banks)</p> <p>Flood shelter: about 2ha of raised land where people can bring livestock. Each shelter has space for over 100 families and includes a toilet</p> <p>Radios to issue warnings</p> <p>Embankments to hold back rising water</p> <p>Sluice gates (able to close channel when water rises)</p> <p>Slope protection (to reduce erosion of embankments)</p>

6. There is discussion about the costs and benefits of hard and soft engineering and debate about which is the better option.

There are two main ways in which you can manage rivers: hard and soft engineering. Hard engineering focuses on humans trying to control the environment and tends to be more expensive. Soft engineering aims to work with the environment and is more ecologically sensitive.



Hard engineering

Raised river banks

Higher banks means the river can hold more water

- ✓ One off costs
- ✓ Relatively cheap
- ✓ Can be used in local, small-scale projects
- ✗ Looks unnatural
- ✗ Increases risk of flooding elsewhere

Straightened river channel lined with concrete

Water will flow quicker through a straighter channel.

- ✓ One off costs
- ✓ Stops local flooding
- ✓ Can be used in local, small-scale projects
- ✗ Expensive
- ✗ Increases risk of flooding elsewhere



Deepened river channel

River is deeper so can hold more water

- ✓ Channel can hold more water
- ✓ Reduces flooding
- ✗ Dredging is an annual job

Dams and reservoirs

Trap and store water and release it in a controlled way.

- ✓ Controls river



- ✓ Reservoirs are multi-purpose and provide electricity
- ✗ Very expensive
- ✗ Reservoirs flood local ecosystems
- ✗ Dams trap fertile silt



Flood walls

Raised walls built around settlement, industry or transportation

- ✓ Effective if the flood is not too extreme
- ✗ Expensive
- ✗ Looks unnatural

Flood storage areas

Water is pumped from rivers and stored in temporary lakes.

- ✓ Effective
- ✓ Relatively natural
- ✗ Large areas of land needed
- ✗ Expensive to set up



Tidal barrier

Prevents flooding at high tide.

- ✓ Protects large areas 'at once'
- ✗ Very expensive
- ✗ Only suitable in estuaries

Soft engineering

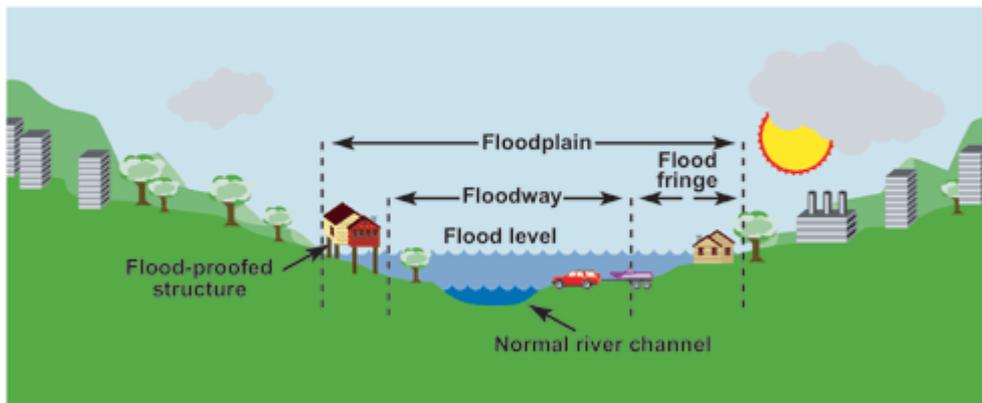
Afforestation

Plant trees to increase interception and absorb water



- ✓ Environmentally aesthetic
- ✓ Relatively cheap and one-off cost
- ✗ Large areas of land needed for tree planting

The floodplain



Floodplain zoning

Closeness to river governs land use.

- ✓ Land use close to river used for animal grazing
- ✓ Land furthest from the river used

for 'expensive' land use, such as hospitals

- ✗ Does not prevent flooding

Flood prediction and warning

The Environment Agency monitors rainfall and river levels and issues warnings to the public.

- ✓ Public are aware of the risks and can take appropriate action
- ✗ Involves many people
- ✗ Continuous nature means that it is expensive



FLOOD WARNING

FLOODING IS EXPECTED. IMMEDIATE ACTION REQUIRED.

- ✗ Does not prevent flooding



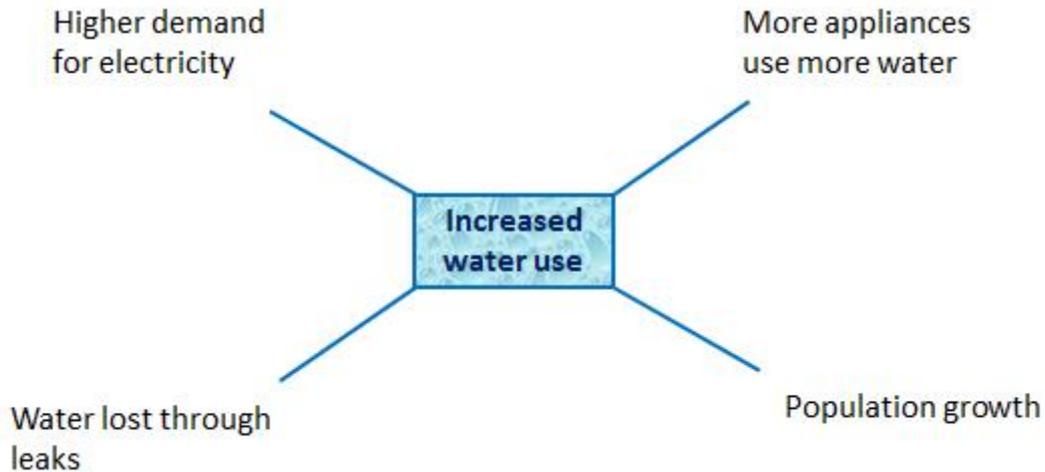
Washlands

Parts of the floodplain are allowed to flood.

- ✓ Prevents valuable land flooding
- ✗ Land can't be 'built', requires low value land to be available for flooding

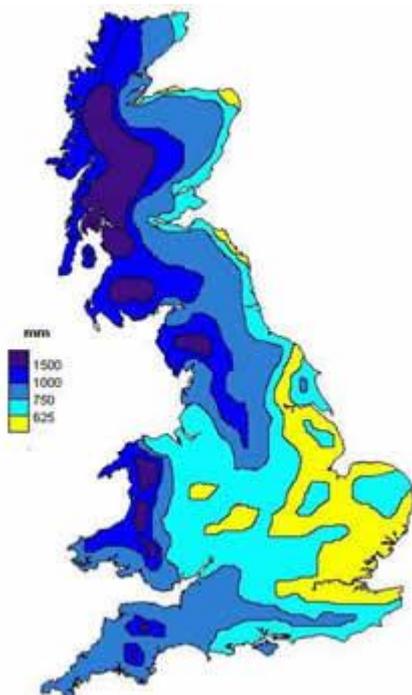
7. Rivers are managed to provide a water supply. There are a variety of issues arising from this.

The UK is experiencing an increasing demand for water.



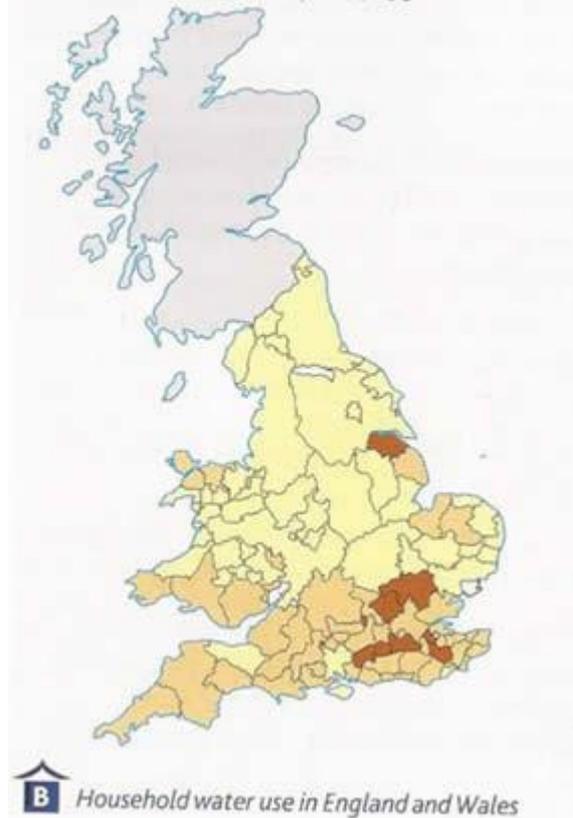
UK Rainfall Water Use

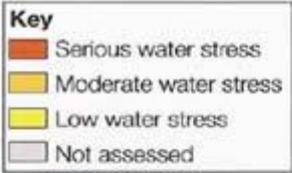
The north and west of the UK receive the highest amounts of rainfall however, demand for household water is at its highest in the south-east. This creates areas of water stress and water supplies in these areas have to be carefully managed. Water has to be transferred from areas with a water surplus to areas with a deficit.



UK Household

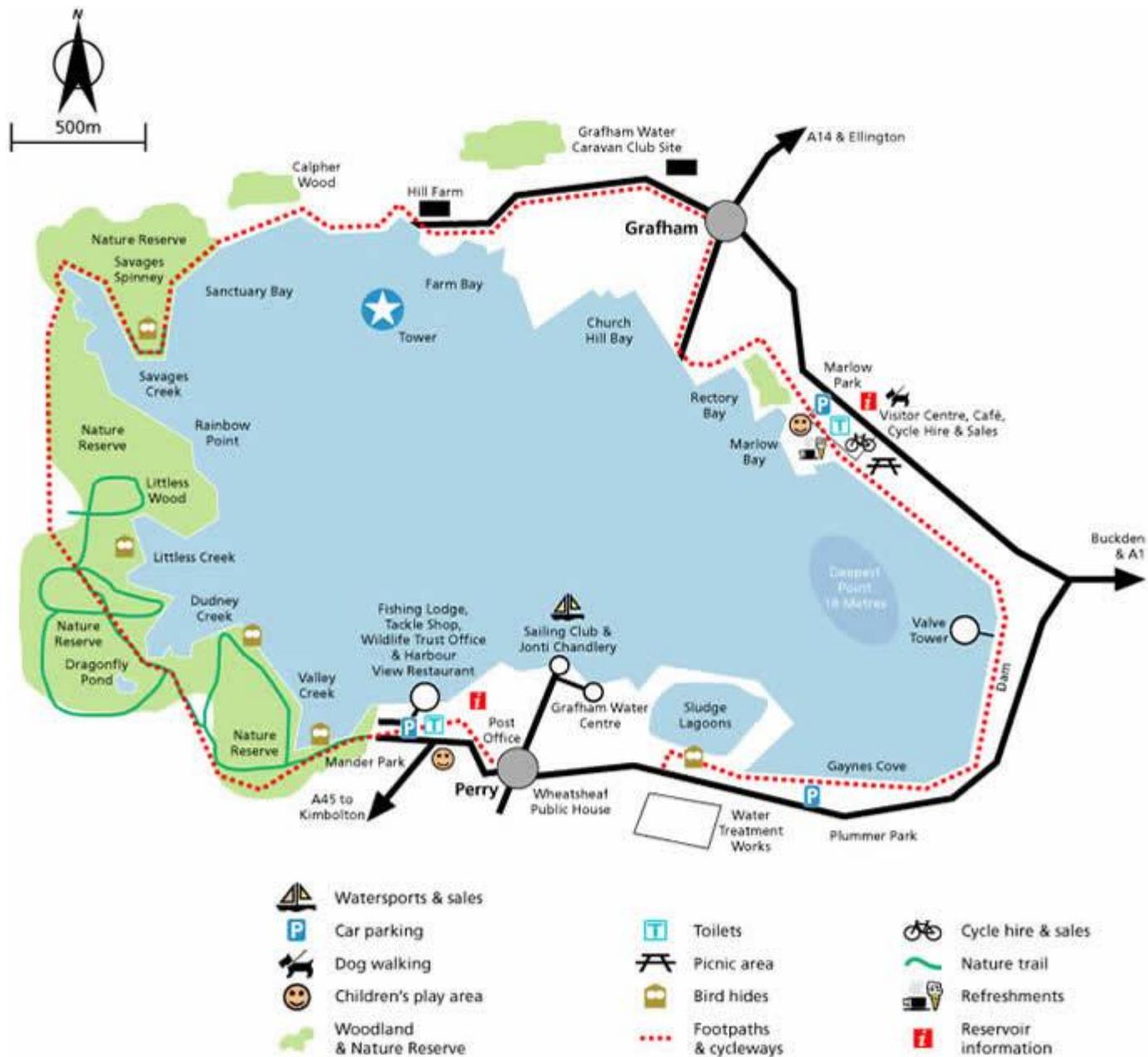
a Actual household use, 2005–06





▲ *Water-stressed areas in England and Wales in 2007*

Grafham Water: a resevoir



What are the social, economic and environmental issues associated with a reservoir and why is there a need for sustainable supplies?

Grafham Water is a reservoir with a circumference of about 10 miles (16km). It is located between the villages of Grafham and Perry in the county of Cambridgeshire. Grafham Water is the eight largest reservoir in England by volume and the third largest by area.

Grafham Water was constructed in the 1960's to meet the demand from the new town of Milton Keynes and the rapid expansion of Bedfordshire and Northamptonshire's existing towns. It was originally a joint project between Mid-Northants Water Board, Great Ouse Water Authority and Bedfordshire County Council but transferred to Anglian Water in 1974.

Originally called Diddington Reservoir after the little brook whose valley it flooded, it was renamed Grafham Reservoir and subsequently Grafham Water. The reservoir is on a plateau with nearly all of its water being abstracted from the River Great Ouse at Offord and pumped up to form the 1500 acre (600 hectare) lake.

In addition to the sailing club a trout fishery and education centre were included in the original design and Sir Peter Scott opened the nature reserve at the western end. Most of the leisure infrastructure you see today was provided in the last 19 years including a visitor centre, cycle hire and route, fishing lodge and restaurant. The water treatment works has been expanded and modernised to meet increasing demand and today's higher quality standards.

	Positive	Negative
Social	Leisure activities e.g. trout fishery, cycle route, restaurant Ensures drinking water for local population	Visual impact for local residents
Economic	Water levels can be controlled to reduce flood risk	Expensive to build
Environmental	Reservoir colonised by wildlife Nature reserve surrounding western side of the reservoir containing semi-natural ancient (at least 400 years old) woodlands and plantation woodlands, grasslands and wetlands habitats such as reedbeds, willow and open water.	Flooded valley around Diddington Brook